Satellite Validation Activities at the Howard University Beltsville Campus

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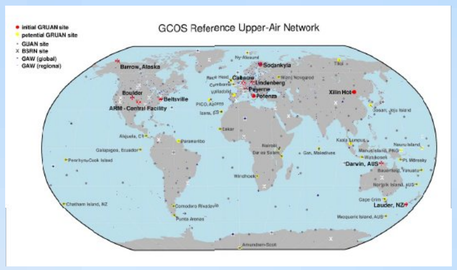
Introduction

The Howard University Beltsville Campus (HUBC), located in Beltsville, Maryland (39.054°N; 76.877°W), (http://meiyu.atmphys.howard.edu/beltsville/inde3.html) is characterized by meteorological conditions that range from semi-tropical, hazy and polluted to cold, dry and nearly pristine. There is a large suite of instrumentation at the site for atmospheric monitoring including active and passive sensors and ozonesounding. Thus, the HUBC site offers a measurement site that has much of the instrumentation of the DOE ARM sites but offers very different meteorology than the ARM sites making it of interest to satellite validation studies. Three NASA-funded Water Vapor Validation Satellite/Sondes (http://ecotronics.com/lidar-misc/WAVES.htm) experiments were hosted at HUBC between 2006 – 2008 under the Aura validation program. The results of those campaigns will be reviewed. Recently, HUBC was identified as a Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) site (GCOS-112, GCOS-121). Regular radiosonde soundings and research into reference quality measurements of water vapor and other climate variables will be performed as part of the GRUAN activities, which are sanctioned by the World Meteorological Organization. Also, a NASA University Research Center was awarded establishing the "Howard University Beltsville Center for Climate System Observation" at HUBC. This 5-yr NASA grant will support intensive measurement campaigns in two general thrust areas of 1) Weather and Climate and 2) Atmospheric Composition.

The Howard University Beltsville Campus

The HUBC site is a 110-acre mostly forested site in a mixed residential, industrial area of Beltsville, MD. The instrumentation available at the site includes Rotating Shadowband Radiometer, Multi-Filter Rotating Shadowband Radiometer, Microwave radiometer, GPS, total sky imager, Intermet and Vaisala RS-92 upper-air sounding systems with ECC capability Broadband radiometers, Raman aerosol and water vapor lidar, sun photometer, 31-m instrumented tower, C-band Doppler Radar (FOX TV), Tipping Bucket Rain gauge, NOx analyzer, Ozone analyzer, CO analyzer. In addition, the Maryland Department of the Environment maintains a research grade monitoring station at the site that provides the following measurements: Ozone, NOx, 56 volatile organic carbons, 7 carbonyls, particulate matter 2.5 and 10 microns, a full set of surface meteorological measurements and doppler radar for upper air wind speeds (to 4 km).

The Howard University Beltsville Center for Climate System Observation and the GCOS Reference Upper Air Network (GRUAN)



Howard University was recently awarded a 5-yr University Research Center grant from NASA. Consistent with the Weather, Climate and Atmospheric Composition thrust of the center, research will be pursued in the following specific areas: 1) GPM validation, 2) Wind Lidar, 3) Aerosol and cloud studies, 4) Tropospheric Ozone, 5) Water vapor variability and temperature. The latter of these research efforts will be strengthened by HUBC's participation in GRUAN. Quoting from GCOS-112, "a network for atmospheric reference observations, is required to provide the foundation for long-term datasets that can be used to reliably monitor and detect emerging signals of global and regional climate change. This network is envisioned to i) provide long-term high quality climate records, 2) constrain and calibrate data from more spatially-comprehensive global observing systems (including satellite and the current upper-air network stations), and 3) fully characterize the properties of the atmospheric column". The Howard University Beltsville Campus (HUBC) has been designated and invited to be one of the twelve initial GRUAN sites. The initial measurements of GRUAN are to consist of a minimum of once weekly sonde launches of best available technology augmented by monthly soundings capable of extending into the UT/LS. One of the goals of GRUAN is also to develop a reference radiosonde that can be used as a standard within the community. Regular GRUAN operations will commence in 2009 at HUBC.

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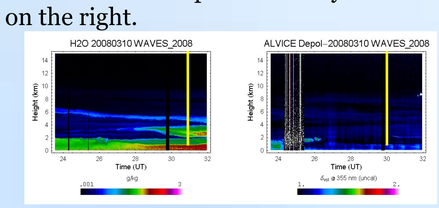
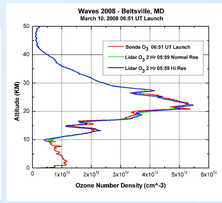
The Water Vapor Validation – Satellite/Sondes field campaigns.

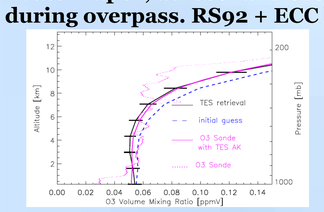
Three WAVES satellite field campaigns were funded under the Aura Validation program and occurred in the summers of 2006 and 2007 and winter of 2008. A summary of the activities is given on the left below. An example case study from March 10, 2008 that is being used for studying TES water vapor and ozone retrievals is shown on the right.

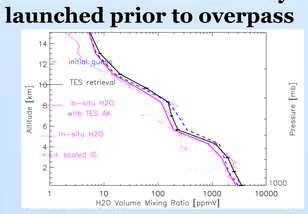
- ***WAVES Accomplishments***
- **Upgraded Beltsville infrastructure to support field campaign activities**
- **>75 A-train overpasses covered under differing seasons**
  - **More than 300 sonde packages including more than 100 RS-92s, 30 CFHs, 60 ECCs, and 6 additional PTU sensor technologies**
    - **NWS operational sonde testing**
  - **Multiple lidar measurements**
- **Aura Validation Papers**
  - **TES : water vapor (Shepherd), ozone (Nassar), temperature (Herman)**
  - **MLS : water vapor (Vömel)**
  - **HIRDLS : ozone (Nardi)**





Water vapor, aerosol and ozone lidars ran continuously during overpass. RS92 + ECC launched prior to overpass

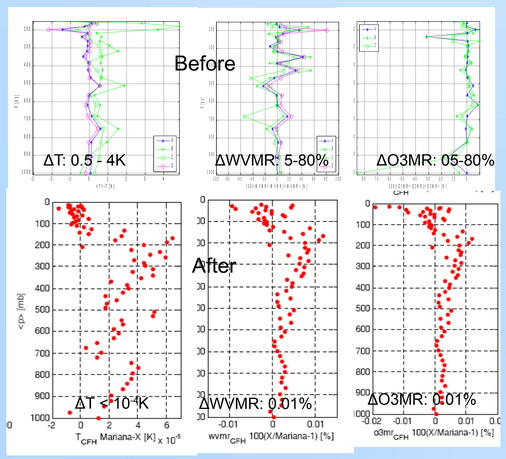




Preliminary retrievals show better agreement for ozone than water vapor.

WAVES Intercomparison Techniques Study

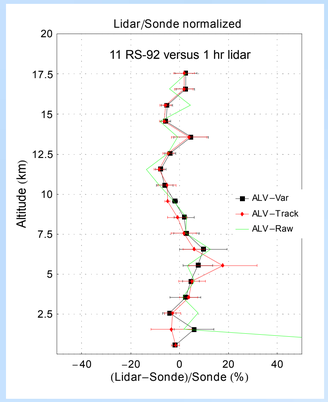
Early in the post WAVES_2006 period, it became clear that different people were drawing different conclusions when analyzing the same data. Because of this, a group was formed involving TES and AIRS team members, NASA/GSFC and Howard University to study techniques for performing the comparison. The plot below shows a before and after comparison of *only the interpolation of radiosonde data to the AIRS 100-layer grid*. As shown in the plots differences that were as large as 4K in temperature and 80% in mixing ratios have been essentially eliminated.



Several areas of disagreement were found among those participating in this study. The differences in the algorithms implemented in the top row of plots (where large disagreements were found) and the bottom row (where near perfect agreement was found) were due to several factors including definitions of mixing ratio, methods of integration, requirement that molecules and radiance be conserved through the interpolation step, methods of eliminating bad data.

NDACC Lidar Validation

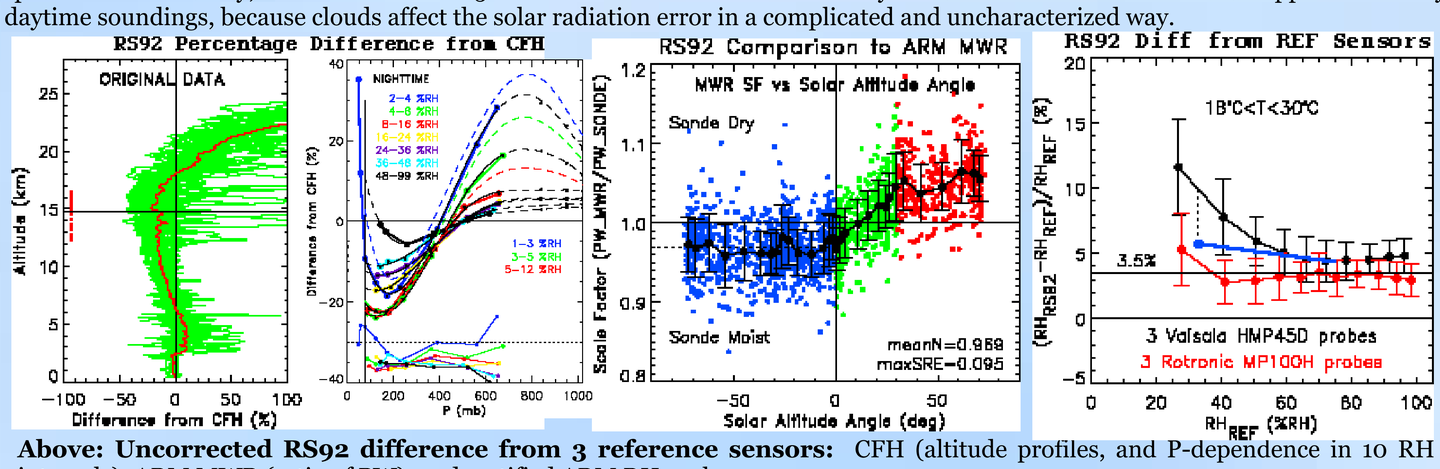
The Network for the Detection of Atmospheric Composition Change (NDACC) has added UT/LS water vapor as one of the constituents that is monitors. The mobile NASA/GSFC ALVICE lidar system has recently been admitted as an NDACC complementary system for the purposes of water vapor intercomparison and validation. HUBC is the default home location of ALVICE and provides opportunities for calibration as shown below.



The plot on the left shows an ensemble comparison of empirically corrected RS92 radiosondes and 1-hr average water vapor profiles from ALVICE during the WAVES_2008 field campaign. The two profilers are in agreement within +/-10% from the surface to 18km, well beyond the tropopause. Continuous measurements from ALVICE, such as shown above, can therefore be used to quantify atmospheric variability during satellite overpass periods.

Reference Water Vapor Sounding and Empirical Correction to Vaisala RS92

Vaisala RS92 mean bias error is characterized by comparing simultaneous measurements from RS92 and three reference instruments of known accuracy. The cryogenic frostpoint hygrometer (CFH) gives the RS92 accuracy above the 700 mb level; the ARM microwave radiometer gives the RS92 PW accuracy; and the ARM SurTHref system gives the RS92 accuracy at the surface using 6 RH probes with NIST-traceable calibrations. An empirical bias correction is derived to remove the mean bias error, yielding corrected RS92 measurements whose mean accuracy is estimated to be 3% of the measured RH value for nighttime soundings and 4% for daytime soundings, plus an RH offset uncertainty of 0.5% RH that is significant for dry conditions. These accuracy figures assume an ensemble of ~16 radiosondes at night and ~4 during the daytime. The accuracy of individual RS92 soundings is further characterized by the 1-σ "production variability," estimated to be ±1.5% of the measured RH value. The daytime bias correction should not be applied to cloudy daytime soundings, because clouds affect the solar radiation error in a complicated and uncharacterized way.



Above: Uncorrected RS92 difference from 3 reference sensors: CFH (altitude profiles, and P-dependence in 10 RH intervals); ARM MWR (ratio of PW); and certified ARM RH probes.
Below: Corrected RS92 mean accuracy is ±2% for all RH conditions from the surface to several km above the tropopause based on comparisons with same sensors as above.